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**APPLICATION FOR UNITED STATES LETTERS PATENT**

**FOR A**

**POSITIVE TEMPERATURE COEFFICIENT  
RESISTIVITY PROTECTED POWER TRANSFORMER**

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## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

5 The present invention relates generally to the suppression of transient energy to transformers and more particularly to a polymer positive temperature coefficient resistivity (PPTC) element which protects power transformers from overload, short circuit and thermal overheating conditions.

### **Description of the Related Art**

It is known in the general art that power transformers typically have to be protected from overload or overcurrent and short circuit conditions. Significant damage, such as insulation damage or fire, may occur to the transformer should an overload or overcurrent or short circuit condition occur.

Prior art devices used in overcurrent or short circuit protection of transformers typically include current limiting fuses, which interrupt all available currents above the fuse's threshold current and below the fuse's maximum interrupting rating.

20 A prior art apparatus in Olesak et al. (U.S. Patent No. 4,810,991), entitled "ENCAPSULATED INTEGRAL FUSE BLOCK TRANSFORMER", comprises a transformer assembly, having primary and secondary windings, a fuse block and means for mounting the fuse block to the transformer. Claimed advantages of the Olesak assembly over the prior art are the conservation of space on a panel board

to which the transformer is mounted and the reduction of time required to assemble the Olesak apparatus, therefore, resulting in lower labor costs in the manufacture of the assembly.

As noted in the Olesak patent, labor costs and the amount of available space on the transformer which may be utilized for circuit protection are important factors in the manufacture of transformers. Current fuse and fuse block assemblies continue to require a significant amount of space and provide a significant disadvantage when integrating other circuitry or electrical components into a panel.

Another disadvantage with the use of a fuse and fuse block assembly is that it may only provide overcurrent and short circuit protection. Current fuse and fuse block assemblies fail to appreciate that thermal cut-off must occur in a power transformer that has become overheated by a source other than the thermal energy created during an overcurrent or short circuit situation. In such situations, a fuse does not provide protection from such overheating condition, thereby causing a degradation, and ultimate failure, of the transformer.

A further disadvantage to the fuse and fuse block system is that the fuse is not reusable and must be replaced after the occurrence of an overcurrent or short circuit event. Replacement of a fuse is an additional expense, a time consuming event and an inconvenience to users. Therefore, equipment manufacturers utilizing power transformers prefer an alternative to a fuse based protection system.

## SUMMARY OF THE INVENTION

5 The present invention provides a transformer having primary and secondary windings and a polymer positive temperature coefficient resistivity element electrically coupled to the primary or secondary winding of the transformer to provide protection against overcurrent, short circuit and overheating conditions.

The polymer positive temperature coefficient resistivity element is thermally and electrically connected to the coil body, preferably the primary winding, of the power transformer. Preferably, the polymer positive temperature coefficient resistivity element is placed in an area of the transformer prone to exhibit an increase in temperature. The resistance of the polymer positive temperature coefficient resistivity element dramatically increases upon the occurrence of an overcurrent, short circuit or overheating event, thereby reducing the current in the transformer to a minimal level. The resistance of the polymer positive temperature coefficient resistivity element increases so greatly that the current through the circuit drops dramatically after an overcurrent, short circuit or overheating event.

20 In another embodiment, a light emitting diode (LED), a P-N junction semiconductor device, which emits optical radiation when forward biased, is electrically coupled to the polymer positive temperature coefficient resistivity element. Upon activation of the polymer positive temperature coefficient resistivity element, voltage across the LED will be sufficient to illuminate it and thereby provide notice to maintenance personnel that a fault situation has occurred.



In yet another embodiment, a solenoid and mechanical switch are introduced into the power transformer and polymer positive temperature coefficient resistivity element circuitry. After activation of the polymer positive temperature coefficient resistivity element, an undesired current flow, leakage current, in the order of a few mill-ampere continues to flow through the power transformer and the polymer positive temperature coefficient resistivity element. This leakage current is of a sufficient magnitude to keep the polymer positive temperature coefficient resistivity element in the activated or tripped state. The solenoid and mechanical switch are introduced into the power transformer and polymer positive temperature coefficient resistivity element circuitry to interrupt all current flow following activation of the polymer positive temperature coefficient resistivity element.

Examples of the more important features of the invention thus have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

For detailed understanding of the present invention, references should be made to the following detailed description of the preferred embodiment, taken in

conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

**FIGURE 1a** illustrates a prior art power transformer utilizing a fuse and fuse block for protection of the transformer in overcurrent and short circuit conditions;

**FIGURE 1b** is a schematic diagram of the prior art power transformer shown in **FIGURE 1a**;

**FIGURE 2a** is a power transformer utilizing a polymer positive temperature coefficient resistivity element for protection of the transformer in overcurrent, short circuit and thermal overheating conditions in accordance with a preferred form of the invention;

**FIGURE 2b** is a schematic diagram of the preferred embodiment shown in **FIGURE 2a**;

**FIGURE 3** is a schematic diagram of an alternative embodiment of the present invention wherein a light emitting diode is electrically connected to the polymer positive temperature coefficient resistivity element to provide a fault situation signal to maintenance personnel;

**FIGURE 4** is a schematic diagram of an alternative embodiment of the present invention wherein a solenoid and switch, each electrically connected to the polymer positive temperature coefficient resistivity element, provide total current interruption; and

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**FIGURE 5** is a schematic diagram of an alternative embodiment of the present invention wherein a solenoid and switch, the solenoid electrically coupled to the polymer positive temperature coefficient resistivity element and the switch electrically coupled to the secondary winding, provide total current interruption.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

The present invention relates to apparatus and methods for protecting a power transformer during overcurrent, short circuit and overheating conditions. The present invention is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein.

As stated above, prior art devices used in overcurrent or short circuit protection of transformers typically include current limiting fuses. **Figure 1(a)** illustrates a prior art power transformer **10** utilizing a current limiting fuse (not

shown), in combination with a fuse block assembly 30, as a protection means.

**Figure 1(b)** is a schematic of the prior art transformer 10 comprising a primary winding 40, a secondary winding 50 and a current limiting fuse 20 electrically connected to the primary winding 40 of the power transformer 10. A power source (not shown) is electrically connected to the primary winding 40 of the transformer 10. In **Figure 1(a)**, a fuse block assembly 30 is positioned atop a transformer coil body 60, comprising the primary winding 40 and the secondary winding 50, and a transformer core 70.

Referring to **Figure 2a**, there is shown a preferred embodiment of the present invention, a polymer positive temperature coefficient resistivity (PPTC) protected power transformer 110. The present invention is a low cost, space saving solution to the fuse and fuse block protected power transformer. In addition to providing overcurrent and short circuit protection, the preferred embodiment provides overheating or thermal cut-off protection, which is not available with the prior art device shown in **Figures 1(a)** and **1(b)**.

For PPTC protected power transformers, there are three types of available protection: (1) overcurrent or overload protection; (2) short circuit protection; and (3) overheating or thermal cut-off protection. The PPTC material has a unique characteristic that allows its resistance to increase dramatically as its temperature increases over a certain value (i.e., 140° C). The resistivity of a PPTC element at a temperature higher than 140° C must be at least 100 times the resistivity of the element at ambient temperature.

In **Figures 2a** and **2b**, the transformer core **170**, comprising laminated steel sheets, is adjacent to the transformer coils **160**, comprising the primary winding **140** and secondary winding **150**. A power source (not shown) is electrically connected to the primary winding **140** of the transformer **110**. The polymer positive temperature coefficient resistivity element **120** is wrapped around the coil body **160**, specifically the primary winding, and is thermally attached to the coil body **160** and the insulating materials. The polymer positive temperature coefficient resistivity element **120** may be attached to the coil body **160** surface as shown in **Figure 2a**. The polymer positive temperature coefficient resistivity element **120** may also be wrapped inside the coil body **160**. In the preferred embodiment, the polymer positive temperature coefficient resistivity element **120** is placed in an area of the coil body **160** prone to exhibit an increase in temperature, thereby providing maximum protection (i.e., overcurrent, short circuit and thermal overheating) of the power transformer **110**. The PPTC temperature is related to the ohmic heating caused by current flow through the polymer positive temperature coefficient resistivity element **120**. Therefore, when the PPTC element **120** is electrically connected in the transformer circuitry, the transformer **110** temperature is controlled by the current flowing through it.

It is emphasized, however, that the present invention is not limited to polymer based materials. Polymer based materials simply exhibit the desired properties that are utilized in the present invention. Thus, other materials, such as ceramic-based

materials (i.e., a BaTiO<sub>3</sub> ceramic) that provide for overcurrent, short circuit and thermal overheating protection may also perform adequately.

Under normal operations, current flow through the power transformer **110**, more specifically, the coil body **160**, will not generate sufficient ohmic heating to initiate operation of the PPTC element **120**. However, when the transformer **110** is placed in an overcurrent situation, for example, the excess current will initiate operation of the PPTC element **120** within a predetermined time period. The resistance of the PPTC element **120** will dramatically increase upon activation, thereby reducing the current within the primary winding **140**, for example, to a minimal value. The transformer **110** is consequently protected from the overcurrent by the PPTC element **120**. When the PPTC protected transformer is under a short circuit situation, the large, short circuit current activates the PPTC element **120** within a few milli-seconds, thereby providing sufficient current limitation to the power transformer **110**.

The PPTC element **120** may also be activated when overheated, for example, by an external heat source. An external heat source could include, for example, any other component or assembly in close proximity to the PPTC element **120**. In a thermal overheating situation, the PPTC element **120** will become activated to protect the transformer **110** from further overheating which results in degradation, and ultimately destruction, of the power transformer **110**.

In the above three fault situations, the PPTC element **120** will reset itself to its original state once the overcurrent, short circuit or overheating is removed and the power source is turned off.

In **Figure 2b**, the PPTC element **120** is preferably connect to the primary winding **140** of the power transformer **110**. Since the primary winding **140** draws much less current than the secondary winding **150** of the power transformer **110**, the PPTC element **120** component size may be smaller for the primary winding **140** application than that for the secondary winding **150** application.

**Figure 3** is a schematic of an alternative embodiment of the present invention. In this embodiment, a light emitting diode (LED) **180** is connected in parallel with the PPTC element **120** and a resistor **185**. The LED **180** may be mounted on a panel board (not shown), which would allow for easy observation. In the event that the PPTC element **120** is activated, the voltage across the LED **180** will be sufficient to illuminate the LED **180** and provide an indication to maintenance personnel that a fault situation has occurred.

Upon activation of the PPTC element **120**, a leakage current continues to flow through the PPTC element **120** and the transformer coil body **160**. This leakage current typically is a few milli-ampere and may be sufficient to keep the PPTC element **120** in the activated state. Should an application require no leakage current, a mechanical switch **190** may be connected in series with the primary winding **140**, as shown in **Figure 4**, or with the secondary winding **150**, as shown in **Figure 5**, of the power transformer **110**. The switch **190**, which is normally closed

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during normal operations, is mechanically linked to a solenoid **200** that is connected in parallel with the PPTC element **120**. As the PPTC element **120** is activated, a current will flow through the solenoid **200** thereby creating a magnetic field and energizing the solenoid **200** to open the switch **190** causing an interruption in current flow and elimination of any leakage current. The switch **190** should remain open after the PPTC element **120** is activated and until the fault is cleared. After the fault have been cleared, the switch **190** can be closed manually.

The foregoing description is directed to particular embodiments of the present invention for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth are possible without departing from the scope and the spirit of the invention. It is intended that the following claims be interpreted to embrace all such modifications and changes.